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Airborne man-made radio noise assessment
by T. N. Roy

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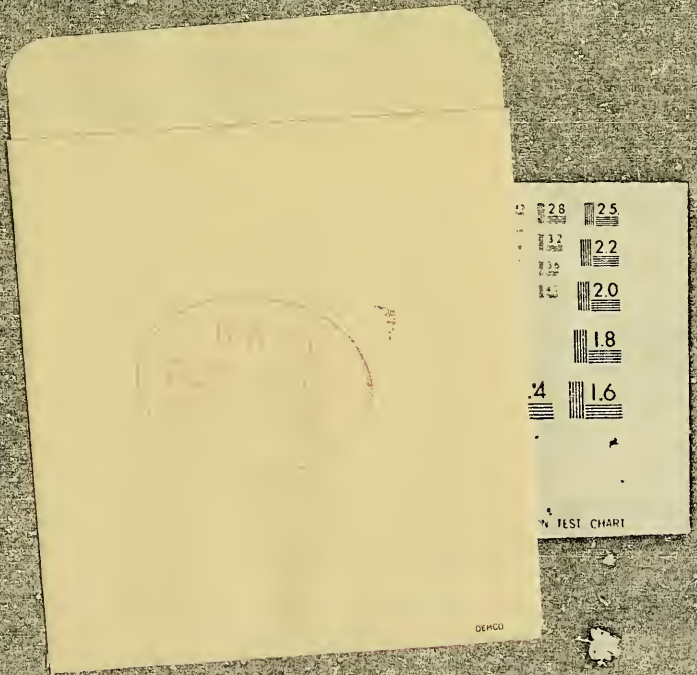

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AIRBORNE MAN-MADE RADIO NOISE ASSESSMENT

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T.N. Roy

15 April 1981

Final Report: March - December 1980

Prepared for
Defense Communications Agency
Naval Electronic Systems Command

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An airborne man-made radio noise model has been developed and programmed on a graphics computer at the Naval Ocean Systems Center. This model provides a useful approximation to the geographical dependence of airborne man-made radio noise in the continental United States. Radio noise maps produced from this model are used to evaluate the effect of man-made radio noise on the operation of meteor burst communication systems.

Equations developed by Skomal (E. N. Skomal, Man-Made Radio Noise, Van Nostrand Reinhold Co., New York, 1978) are used to construct the model. Two parametric equations are used to model the height gain of man-made radio noise as a function of distance, 0 to 150 miles, from the source. (Cont.)

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SUMMARY

An airborne man-made radio noise model has been developed and programmed on a graphics computer at the Naval Ocean Systems Center. This model provides a useful approximation to the geographical dependence of airborne man-made radio noise in the continental United States. Radio noise maps produced from this model are used to evaluate the effect of man-made radio noise on the operation of meteor burst communication systems.

Equations developed by Skomal (EN Skomal, Man-Made Radio Noise, Van Nostrand Reinhold Co., New York, 1978) are used to construct the model. Two parametric equations are used to model the height gain of man-made radio noise as a function of distance, 0 to 150 miles, from the source. Coefficients for these equations are calculated from data measured over Seattle (WE Buehler and CD Lunden, IEEE Trans. Electromagnetic Compatibility, EMC-8, 143-152, 1966).

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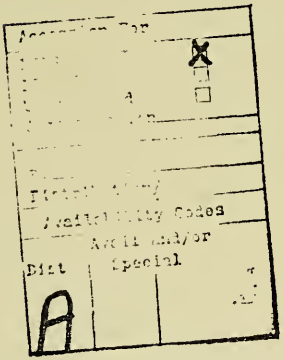

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1.0 INTRODUCTION

The assessment of airborne man-made radio noise began as an effort to more completely understand the factors influencing performance of Meteor Burst Communication Systems (MBCS). These systems are under investigation here at the Naval Ocean Systems Center (NOSC) to determine their potential application to the Minimum Essential Emergency Communication Network (MEECN).[1] Operation of MBCS depends upon the reflection of vhf (30-100 MHz or more) radio signals from ionized meteor trails as shown in figure 1. Testing required to evaluate the performance of these systems involves transmission and reception of vhf signals both on the ground and when airborne. External interference affecting the reception of these signals includes galactic noise, local atmospheric noise, and man-made noise. Of the three types of interference encountered during airborne tests, man-made noise near metropolitan areas was the most severe. The effect of this interference on a MBCS is to increase the system waiting time for transmission of an error-free message.

The airborne MBCS experiments have shown that man-made radio noise can be measured at distances in excess of a hundred miles from large metropolitan areas. Noise was found to increase with altitude and the minimum noise level, galactic noise, was found only over open ocean. In general, the level of man-made radio noise was worse than expected and it was decided that an assessment of the characteristics of airborne man-made radio noise would be necessary to evaluate the utility of Meteor Burst Communication Systems.

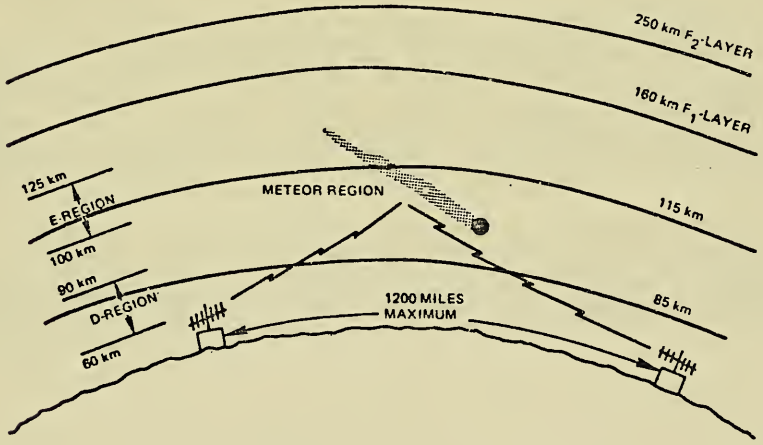

Figure 1. Meteor Burst Communication System.

An airborne man-made radio noise model was developed and programmed on a graphics computer at NOSC to aid in the evaluation. Parametric equations developed by Skomal[2] are used to model the height gain of man-made radio noise as a function of distance from the source. Coefficients for these equations are calculated from data measured over Seattle by Buehler and Lunden.[3] To provide a useful approximation to the geographical dependence of airborne man-made radio noise in the continental United States, two hundred of the nation's largest cities and 62 of the largest counties and military installations are used as sources of radio noise in the model.

Radio noise maps are produced using this model and are used to evaluate the effect of man-made radio noise on the operation of MBCS. These maps show that very little of the continental United States is free of airborne man-made radio noise. Minimum noise levels are found during the night at low altitudes for distances greater than 100 miles from most metropolitan areas.

2.0 SURFACE MAN-MADE RADIO NOISE

Perhaps the first known case of man-made interference to radio signals occurred in 1902 when Dr. A. Hoyt Taylor heard ignition noise from a two-cylinder automobile. Today, man-made radio noise extends to all continents and is detectable at subsynchronous satellite altitudes in the frequency range of 30 Hz to 7 GHz.

Man-made radio noise is of three types: (1) incidental radiation from electric power lines, ignition systems, electric motors, home electrical appliances; (2) intentional radiation such as wireless announcing systems, campus radio stations, walkie-talkies, door-opener transmitters, and licensed transmitters; and (3) unintentional radiation from cable TV systems, microwave ovens, industrial heaters, medical diathermy equipment, RF-stabilized arc welders, and many others.[4] The lower portion of the spectrum is dominated by industrial, scientific and medical equipment, with power line and automobile ignition noise becoming major contributors around 30 MHz and ignition noise achieving a position of dominance at and above 100 MHz.

Surface man-made radio noise has an impulsive distribution with frequency and approaches a thermalization (Gaussian distribution) with increasing altitude. This thermalization increases with increasing frequency also. Figure 2 shows median daytime values of surface man-made radio noise power in terms of Fa (dB above thermal noise at 288°K) as a function of frequency for business, residential, rural and quiet rural areas.[5] Business areas are defined as the

Frequency (MHz)	Business Area		Residential Area		Rural Area	
	D_u (dB)	D_ℓ (dB)	D_u (dB)	D_ℓ (dB)	D_u (dB)	D_ℓ (dB)
0.25	8.1	6.1	9.3	5.0	10.6	2.8
0.5	12.6	8.0	12.3	4.9	12.5	4.0
1.0	9.8	4.0	10.0	4.4	9.2	6.6
2.5	11.9	9.5	10.1	6.2	10.1	5.1
5.0	11.0	6.2	10.0	5.7	5.9	7.5
10.0	10.9	4.2	8.4	5.0	9.0	4.0
20.0	10.5	7.6	10.6	6.5	7.8	5.5
48.0	13.1	8.1	12.3	7.1	5.3	1.8
102.0	11.9	5.7	12.5	4.8	10.5	3.1
250.0	6.7	3.2	6.9	1.8	3.5	0.8

Table 1. Upper, D_u, and lower D_ℓ, decile values in dB of surface noise power variability within an hour at a given location.

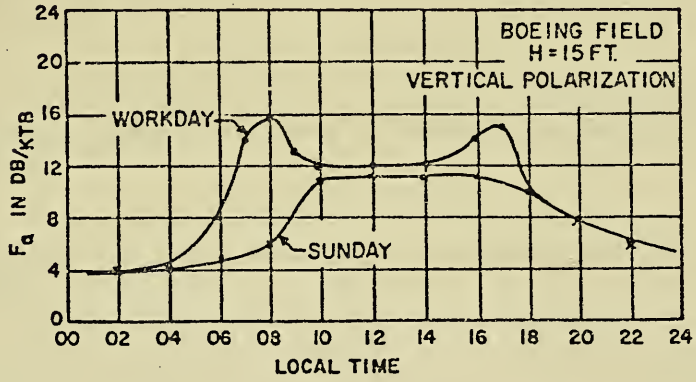

Figure 3. Diurnal variation of 73 MHz surface noise power measured at Boeing Field, Seattle for a workday and a Sunday (Buehler et al., 1968).

From the observed frequency dependence of surface man-made radio noise, Skomal[2] has shown that the surface noise power function, P_s (f,d), expressed in units of power, watts per bandwidth, displays an inverse dependence upon frequency, f, and distance, d. When expressed in decibels relative to 1 mW per detection bandwidth, b, (dBm/b)

$$P_s\ (f,d) = E_1 + E_2\ (d-k) + E_3\ (d-k)^2, \tag{1}$$

where k is a constant which when set to 2.5 miles provides a good representation of vhf and uhf surface radio noise data. Coefficients E_i ($E_i = a_i + b_i f$, i = 1, 2 and 3) in the above equation contain the frequency dependence of the surface noise power function and are determined from three constraints placed on the above equation at a specified frequency, f.

1. At the point d = 0 the derivative of P with respect to d,

$$\left.\frac{\partial P}{\partial d}\right|_{d=0} = 0, \tag{2}$$

a condition that has been observed to occur for composite urban man-made radio noise data.[2]

2. At d = 2.5 miles the noise power function at frequency f_m in MHz equals a least-squares-regression line derived from business zone data in dBm/b,

$$P_a = -89.9 - 12.3 \log f_m, \text{ and} \tag{3}$$

3. At d = 10 miles the noise power function at frequency f_m equals a least-squares regression line derived from residential zone data in dBm/b,

$$P_b = -92.5 - 12.7 \log f_m. \tag{4}$$

Using these constraints to solve equation (1) for coefficients E_1, E_2 and E_3 gives

$$E_1 = P_a, \tag{5}$$

$$E_2 = 5\ E_3, \text{ and} \tag{6}$$

$$E_3 = (P_b - P_a)/93.75. \tag{7}$$

Calculation of surface noise power can now begin with selection of the frequency and the determination of the three coefficients of equation (1). Substitution of the coefficient values into equation (1) and setting x equal to 2.5 miles allows the calculation of surface noise power as a function of distance.

Figure 4 shows the surface noise power function, P_s, in units of power, watts per bandwidth, graphed as a function of distance from the center of a business area for 30, 50 and 70 MHz.

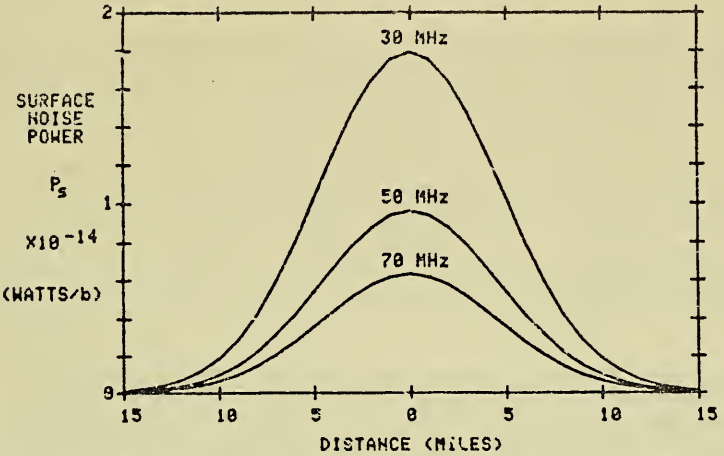

Figure 4. Surface man-made radio noise power, in watts per bandwidth, calculated for 30, 50, and 70 MHz, and plotted as a function of distance from the center of a business area.

3.0 AIRBORNE MAN-MADE RADIO NOISE

Airborne man-made radio noise measurements have been made above many American cities at various altitudes in the frequency range from 1 MHz to 1 GHz. Measurements using forward-directed antennas have detected man-made radio noise in excess of 200 miles from large cities. They indicate that airborne man-made radio noise from a distant metropolitan area can be detected once the aircraft rises above the local optical horizon. At high altitudes, above 10,000 feet, measurements made with a low-directivity antenna show a broad noise signature that is representative of the entire metropolitan area. Measurements made below 10,000 feet with a high-directivity antenna show more detail of local noise sources due to the smaller surface area subtended by the antenna pattern.

Measurements over Seattle[6] using horizontally and vertically polarized antennas indicate that airborne man-made radio noise does not have a predominant polarization. When viewed from above, the radiation field propagating from a two-dimensional surface distribution of independent noise sources should be unpolarized. Airborne measurements using downward-directed isotropic antennas do not show significantly greater radio noise than linearly polarized antennas.

Calculation of man-made radio noise power, P_h, at altitude h, depends upon the knowledge of: (1) the losses and pattern function of the measuring antenna; (2) the distribution of the man-made surface noise sources as a function of position and frequency; (3) transmission path losses; and (4) the degree of correlation between noise sources of adjacent surface areas.

Given the above information, P_h may be represented as an integral, which in the general case, requires numerical evaluation. The degree of difficulty in evaluating the integral varies with the power pattern of the receiving antenna, the function representing the surface noise distribution and the surface area covered by the antenna pattern. For an isotropic antenna positioned above the center of a symmetrical surface noise distribution, evaluation of the integral is much simpler. In addition, transmission path absorption can be assumed to be zero for frequencies less than 3 GHz and observation altitudes of less than 10 miles.

Correlation between man-made noise sources is not well known. Limited data suggest that for altitudes above a few thousand feet there is no correlation. This allows the treatment of man-made noise power from single sources as additive quantities. All man-made noise sources can be considered to be distributed two-dimensionally on a plane that is parallel to and near the surface. Also, the noise power emission from any unit area on the two-dimensional distribution may be assumed to be uniform. This assumption implies that the earth and physical surroundings are either good noise-absorbing or noise-scattering media or both.

Based on the above assumptions and limitations the integral representation of airborne man-made noise power P_h in watts per unit bandwidth b taken from reference 2 is

$$P_h = A_r \int \frac{P_s(f,d)\ F(\gamma_1,\gamma_2)}{4\pi R^2}\ dA. \tag{8}$$

As shown in figure 5 the observing antenna is positioned above a business area at height h, with a separation R between the antenna and differential element dA containing the noise sources. A_r is the antenna aperture area and $F(\gamma_1,\gamma_2)$ is the normalized (to unity) power pattern of the receiving antenna in terms of angle variables (γ_1,γ_2).

When the airborne antenna is a dipole, its effective area becomes identically equal to the area of antennas used for most surface noise measurements. The normalized power pattern may be written for a vertical dipole or monopole antenna in terms of angle variables from figure 5 as:

$$F(\gamma_1,\gamma_2) = \frac{\cos^2(\tfrac{1}{2}\pi \sin\theta)}{\cos 2\theta}\ . \tag{9}$$

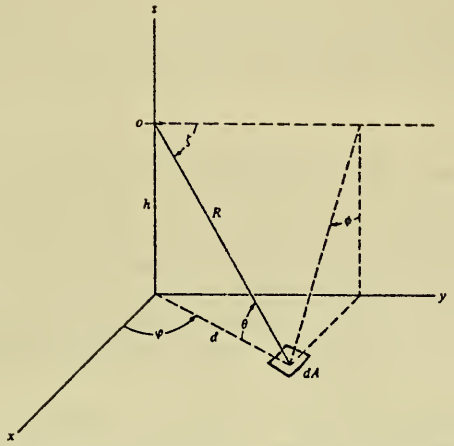

Figure 5. Coordinate system for an airborne antenna, O, located at an altitude, h, above a surface distribution of man-made radio noise sources.

Substitution of the dipole antenna power pattern into the integral representation of the airborne man-made noise power equation and further derivation for offset, business locations performed in reference 2 yield the following parametric equations.

For airborne man-made radio noise directly over a business area when the ratio of altitude, h, to distance, d, is small the limit of the integral is

$$P_h = P_s - A \ln (h/h_o). \tag{10}$$

In the limit of large h/d the integral approaches

$$P_h = kh^{-2}. \tag{11}$$

As h approaches infinity P_h reaches galactic noise as a limit.

For airborne man-made radio noise offset from a business area in the altitude range of $0 \leq h \leq 7.5$ miles, a second-order approximation of the integral is

$$P_h = P_s + Bh - CH^3. \tag{12}$$

To use parametric equations (10), (11), and (12) for the calculation of airborne man-made radio noise power the values of integration constants A, h_o, k, B and C must be known. Calculation of these constants requires airborne man-made radio noise data for at least two different altitudes directly above and offset from a business area.

4.0 AIRBORNE MAN-MADE RADIO NOISE MODEL

To evaluate how well the above parametric equations describe airborne man-made radio noise, a search to locate airborne man-made noise data as a function of altitude and distance from a metropolitan area was initiated. The goal was to find data with sufficient detail to allow construction of an airborne man-made radio noise model valid for altitudes between 30 and 70 thousand feet and horizontal distances from the city center out to 300 miles in the frequency range of 30 to 70 MHz. It was felt that a model in this region would be most useful for a MBCS radio noise model.

An extensive search located only a limited amount of data at frequencies and distances of interest. However, one set of contours was quite complete, showing vertical (0 to 100 thousand feet) and horizontal (0 to 100 miles) values of daytime 1 MHz airborne radio noise power measured and computed for the Seattle area.[3] These contours were replotted by Gierhart, Hubbard and Glen[7] and noise power curves for 30 and 80 thousand foot altitudes were digitized to provide data for the airborne man-made radio noise model. At distances greater than 10[illegible] miles, the above curves were extended using the $1/R^2$ distance dependence exhibited by the near field data at low angles.

To make use of this 1 MHz data for a radio noise model in the 30-70 MHz frequency range, it was assumed that the curves of reference 7, properly scaled, would be representative of the spatial distribution of man-made radio noise at higher frequencies. Additional Seattle data taken at three other frequencies of interest but at only one altitude and two different horizontal distances, were used to check this assumption.[3,4,6] Table 2 shows airborne vhf radio noise power data at an altitude of 5000 feet for frequencies of 29, 49, and 73 MHz compared to corresponding scaled data points from the complete set of data at 1 MHz.

Frequency (MHz)	29		49		73	
Distance (miles)	0	16	0	16	0	16
Data (refs 2, 4, 6)	38.0	28.0	31.7	22.0	27.8	17.7
Scaled 1 MHz data	39.1	27.2	31.6	22.0	26.6	18.6
Factor	.596		.482		.406	

Table 2. Comparison of radio noise power, F_a (dB/kTb) as a function of frequency for distances of 0 and 16 miles.

As can be seen, the scaled 1 MHz curve was found to fit the 29 to 73 MHz noise data at 5000 feet to within about 1 dB. It was assumed that scaled curves at the higher altitudes of 30 and 80 thousand feet would also fit.

The scaling factors shown at the bottom of table 2 are used in a Lagrange interpolation formula to scale the 1 MHz noise power data to any frequency in

the range from 29 to 73 MHz. The Lagrange interpolation formula is

$$S(f) = \sum_{k=\phi}^{3} \left[\prod_{\substack{i=\phi \\ i \neq k}}^{3} (f - f_i)/(f_k - f_i) \right] S_k , \tag{13}$$

where S(f) is the desired scaling factor for frequency, f, and f_i are the three frequencies for which scaling factors, S_k, have been calculated.

Evaluation of the parametric equations using the NOSC computer and daytime radio noise power data at 30 thousand feet, p_{30}, and 80 thousand feet, p_{80}, indicates that for horizontal distances of 0 to 7 miles and altitudes between 5 and 80 thousand feet the equation for noise power in watts per bandwidth,

$$p_h = p_s - A \ln (h/h_o), \tag{14}$$

where

$$A = (p_{80} - p_{30})/\ln (h_{30}/h_{80}) \tag{15}$$

and

$$h_o = h_{80}\, e^{-((p_s - p_{80})/(p_{80} - p_{30}) \ln (h_{30}/h_{80}))} \tag{16}$$

gives good agreement to within a few dB of the scaled Seattle data. This is shown on the right side of the graph in figure 6 where the solid line represents the model and crosses indicate Seattle data taken directly over the city and scaled from 1 MHz to 45 MHz. For horizontal distances of greater than 7 miles and altitudes from 5 to 80 thousand feet the equation for noise power in watts per bandwidth,

$$p_h = p_s + Bh - Ch^3, \tag{17}$$

where

$$B = (p_{30} - p_s)/h_{30} + Ch_{30}^2 \tag{18}$$

and

$$C = (p_{80} - p_s)/(h_{30}^2 h_{80} - h_{80}^3) - (p_{30} - p_s)/(h_{30}^3 - h_{30} h_{80}^2) \tag{19}$$

also gives good agreement to within a few dB of the scaled Seattle data. This is shown on the left side of the graph in figure 6 where again the solid line represents the model and crosses indicate Seattle data taken 50 miles from the city and scaled from 1 MHz to 45 MHz.

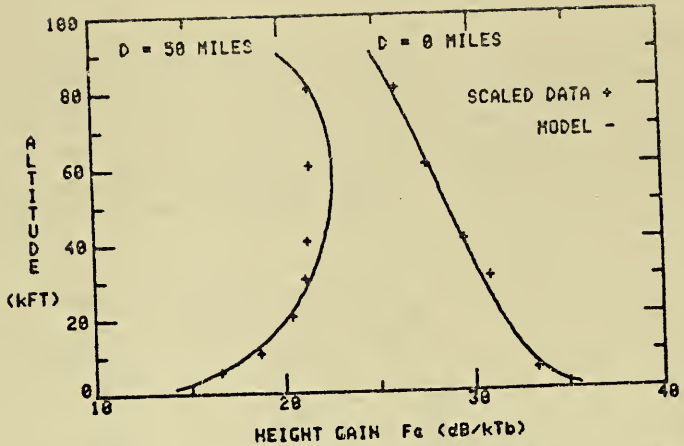

Figure 6. Comparison of daytime 45 MHz man-made radio noise model (solid line) and scaled Seattle data (crosses) directly above and 50 miles from a business area. Height gain, F_a (dB/kTb), is plotted as a function of altitude in thousands of feet.

The airborne man-made radio noise model has been programmed on a graphics computer at NOSC. A series of programs generate graphs of radio noise power in three different formats. In the first format, the vertical profile program produces height gain curves for any frequency and horizontal distance from the source that are selected in the range of the model. In the second format, the horizontal profile program produces radio noise power curves, for a selected frequency and altitude, as a function of horizontal distance. In the last format, the contour program produces contours of constant radio noise power, for a selected frequency and altitude, for the continental United States. Each of the three types of model formats will be discussed in the following sections.

4.1 VERTICAL PROFILE (HEIGHT GAIN)

This program produces height gain curves over the following ranges; frequencies from 30 to 70 MHz, distances from 0 to 300 miles from the source, altitudes from 1 to 90 thousand feet for business, residential and rural areas for day and nighttime conditions. To produce a vertical profile, the frequency is selected first. This allows calculation of surface noise and galactic background noise values similar to those shown in figure 2. Once the horizontal distance is selected, the proper parametric equation is chosen. Equation (17) is used for distances of 7 miles or less and equation (20) is used for distances greater than 7 miles. Coefficients are then calculated and scaled for the proper frequency as discussed in the previous section. If the vertical profile is to be evaluated at night, the calculated daytime radio

noise power is reduced by the diurnal variation similar to that shown in figure 3. Finally, the classification of the area to be modeled is selected and if residential or rural areas are selected, the calculated radio noise power is reduced from the business area value as shown in figure 2. Daytime 45 MHz vertical profiles at distances of 0, 8, 50 and 100 miles from the center of a business area are shown in figure 7. Altitude, in thousands of feet, is plotted on the vertical axis with the height gain, F_a, plotted in dB/kTb along the horizontal axis. Note the increase in height gain at a distance of 50 miles from the business center.

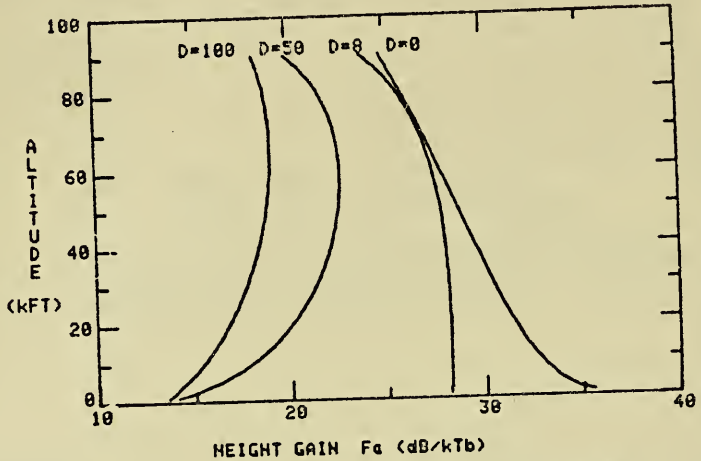

Figure 7. Daytime 45 MHz man-made radio noise model for distances of 0, 8, 50 and 100 miles from the center of a business area. Height gain (F_a (dB/kTb), is plotted as a function of altitude in thousands of feet.

4.2 HORIZONTAL PROFILE

This program produces horizontal profiles of airborne man-made radio noise from the city center out to 150 miles for altitudes from 1 to 90 thousand feet. Operation of the horizontal profile program is the same as the vertical profile program except the variable to be selected is the altitude at which the horizontal profile is to be plotted. Figure 8 shows horizontal profiles at altitudes of 10 and 80 thousand feet above a business area center during the daytime for 45 MHz. Antenna noise factor, Fa, in dB/kTb is plotted on the vertical axis and distance from the area center in miles is plotted along the horizontal axis. Note how the noise peak above the city widens with increasing altitude.

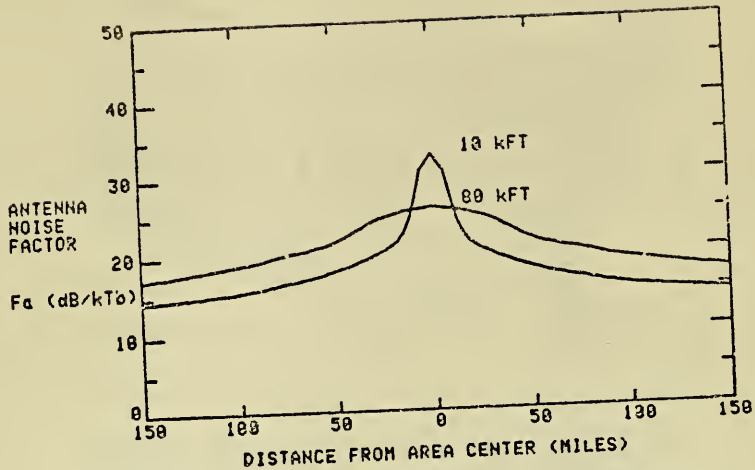

Figure 8. Daytime 45 MHz man-made radio noise model for altitudes of 10 and 80 thousand feet above a business area. Radio noise power, F_a (dB/kTb), is plotted as a function of distance in miles from the city center.

4.3 CONTOURS

The airborne man-made radio noise model can produce contours of constant radio noise power using the contour computer program. This program has been developed to provide a useful approximation to the geographical dependence of airborne radio noise in the continental United States. Radio noise maps produced by this program are used to evaluate the effect of man-made radio noise on the operation of MBCS.

Two hundred of the nation's largest cities and 62 of the largest counties and military installations are used as sources of man-made radio noise in the computer program.[8] Noise calculations are made for the continental United States on a rectangular grid with intervals every 50 miles. Contours are calculated from this grid of data for frequencies between 30 and 70 MHz at altitudes from 5 to 90 thousand feet for day and nighttime conditions. Figure 9 shows daytime 45 MHz contours for an altitude of 5 thousand feet. Contours of constant radio noise power in dB above kTb are plotted for values of 15, 20, and 25 dB. Shaded areas in the continental United States represent areas containing noise power 3 dB or less above galactic noise. At this altitude the 30 dB contours are too small to be resolved on a map of this scale.

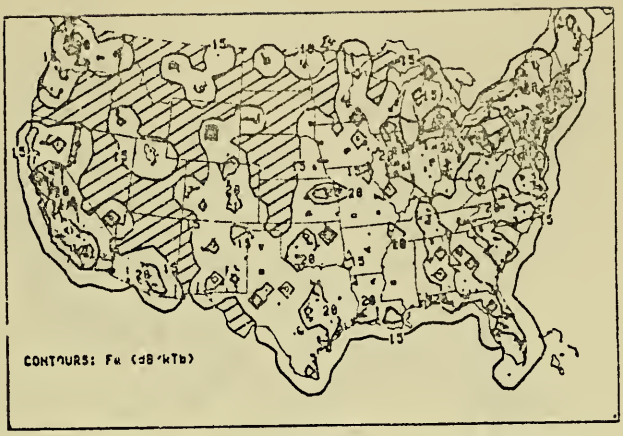

Figure 9. Daytime 45 MHz airborne man-made radio noise map of the continental United States for an altitude of 5 thousand feet. Shaded areas represent noise power 3 dB or less above galactic noise.

In figure 10, daytime 45 MHz contours for a 10 thousand foot altitude are shown. Smaller shaded areas indicate increasing noise at large distances from business areas characteristic of the height gain illustrated earlier. The 30 dB contours are still too small to be resolved. The effects of height gain are clearly shown in figure 11. Daytime 45 MHz contours for a 30 thousand foot altitude are shown on this map. Note the large 30 dB contours above the most populous areas of the country and the disappearance of shaded areas indicating low noise.

The full effect of height gain is shown in figure 12. Daytime 45 MHz contours for an altitude of 70 thousand feet are shown. Notice that the 30 dB contours have expanded to cover a major portion of the eastern United States. Comparison of figures 13 and 14 with the preceding two figures shows the diurnal variation of airborne radio noise. Nighttime 45 MHz contours for 30 and 70 thousand foot altitudes are shown on these maps. Note the reappearance of shaded areas in the western United States indicating low noise. Figures 15 and 16 show the effect of frequency on airborne man-made radio noise. As can be seen, these daytime radio noise maps calculated for an altitude of 30 thousand feet show decreasing radio noise with increasing frequency.

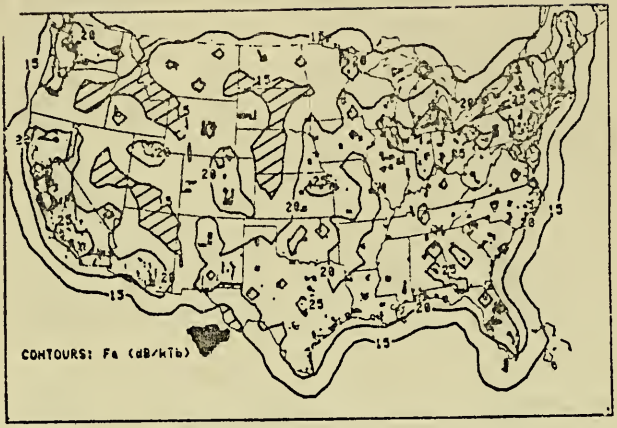

Figure 10. Daytime 45 MHz airborne man-made radio noise map of the continental United States for an altitude of 10 thousand feet.

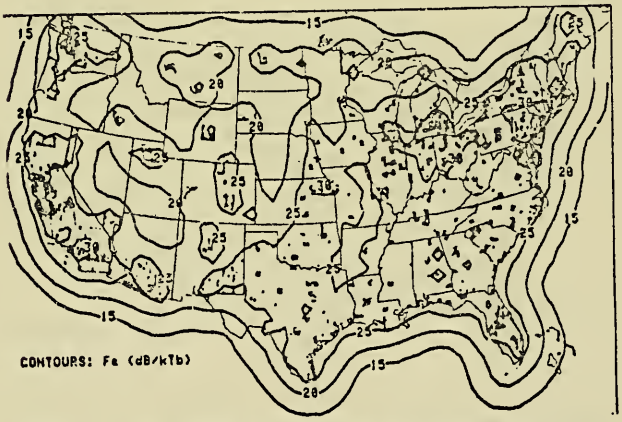

Figure 11. Daytime 45 MHz airborne man-made radio noise map of the continental United States for an altitude of 30 thousand feet.

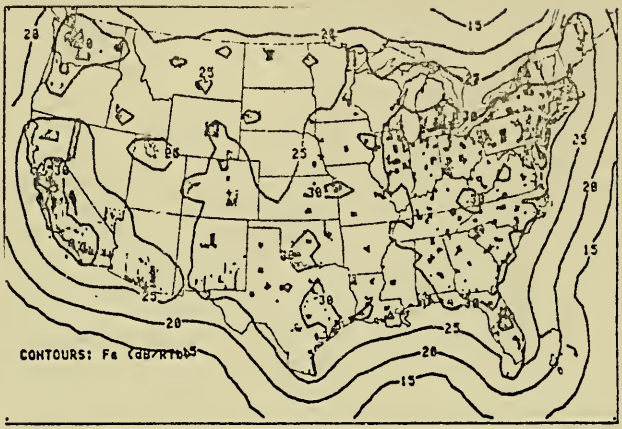

Figure 12. Daytime 45 MHz airborne man-made radio noise map of the continental United States for an altitude of 70 thousand feet.

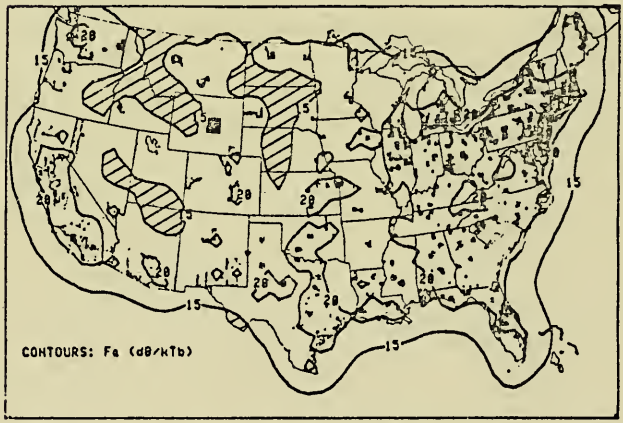

Figure 13. Nighttime 45 MHz airborne man-made radio noise map of the continental United States for an altitude of 30 thousand feet.

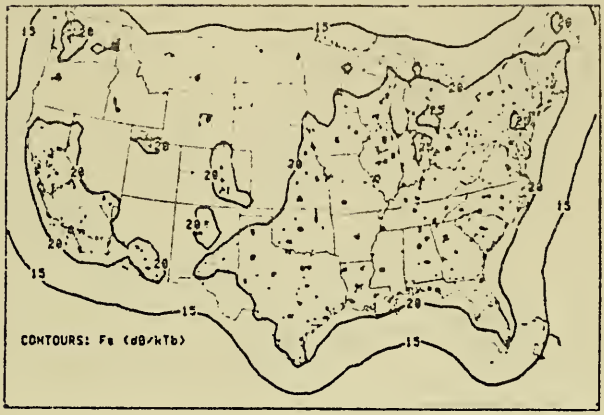

Figure 14. Nighttime 45 MHz airborne man-made radio noise map of the continental United States for an altitude of 70 thousand feet.

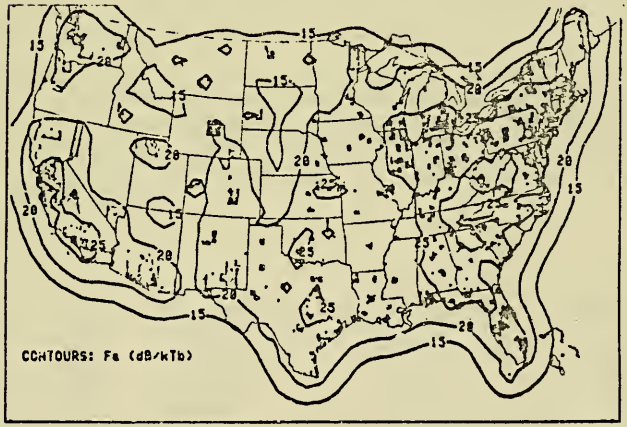

Figure 15. Daytime 30 MHz airborne man-made radio noise map of the continental United States for an altitude of 30 thousand feet.

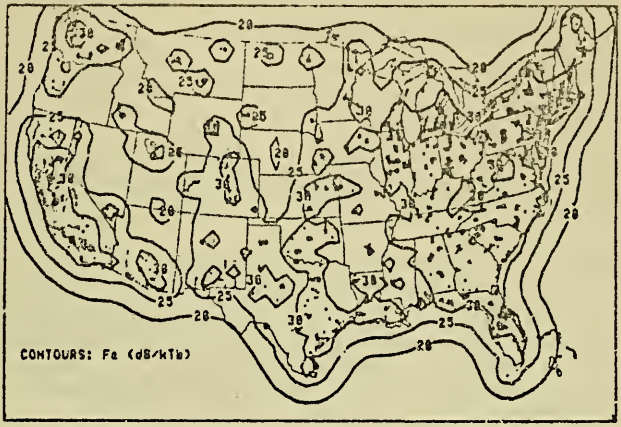

Figure 16. Daytime 70 MHz airborne man-made radio noise map of the continental United States for an altitude of 30 thousand feet.

4.4 COMPARISON OF MODEL PREDICTIONS WITH RECENT DATA

Limited data at the frequency of interest does exist from previous MBCS test flights. Qualitative data from early test flights noted the increase of man-made radio noise with altitude and the existence of radio noise at ranges in excess of 100 miles. This is in agreement with the radio noise model. More recent MBCS data shown in Table 3 for flights over Ft. Worth and Houston, Texas and several hundred miles out over the Gulf of Mexico, are also in agreement with the model.

Location	Time	Altitude (Ft)	Flight Data (F_a)	Model (F_a)
Ft. Worth	0430	7,000	27	27
Houston	0507	7,000	28	27
Houston	1141	16,000	33	32
Gulf	0617	29,000	15-19	16

Table 3. 45 MHz airborne man-made radio noise, MBCS flight data and model comparison.

5.0 CONCLUSIONS

The airborne man-made radio noise model is expected to be representative of almost all large cities, New York City being the only known exception. Existing data show that there appears to be a maximum density of man-made noise sources, such as automobiles, in a metropolitan area. Continued growth shows a tendency to turn surrounding residential noise areas to business noise areas thus increasing the area classified as business. All noise sources used to produce the continental United States man-made radio noise maps are assumed to be business areas.

The airborne radio noise model was developed to cover the frequency range of 30 to 70 MHz and altitudes from 30 to 80 thousand feet. However, the model shows good agreement with scaled Seattle data for altitudes from 5 to 80 thousand feet. Further verification of the model must await the collection of data in the frequency range of interest for many different areas. An improvement to the model, as indicated in the data of reference 3, would be the addition of ground conductivity along the propagation path. In addition, other modes of propagation besides line-of-sight should be considered.

Examination of figures 9 through 16 shows that very little of the continental United States is free from man-made radio noise during daytime. Because of the height gain, increasing the altitude up to 80 thousand feet does not significantly reduce the noise level. Changing frequency in the 30 to 70 MHz range has some effect, due mainly to a reduction in galactic noise at higher frequencies. It is recommended that to reduce the interference of man-made radio noise on the operation of ABCS reception of these signals be carried out, as much as possible, at low altitudes, in rural areas, at night and/or over large bodies of water of at least 100 miles diameter or more.

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